Project Title: Use of a Coupled Biophysical Model for Development of an Index of Biological Productivity in the Coastal Upwelling Zone of the Northern California Current (Year 2)

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Goals:

(1) Produce a "biological productivity-upwelling index" for the Northern California Current (NCC) coastal upwelling zone using a coupled biophysical model calibrated to a time-series of nutrient and plankton observations for the Newport Hydrographic (NH) Line. (2) Relate this index to early-ocean salmon survival to improve short-lead forecasts of salmon run sizes used in harvest management.

Approach:

Our approach to developing the biological production index involved a number of steps:

1. Consolidate nutrient and plankton observation time series for the NH line, 1997-present.
2. Develop a simple model that couples wind-driven upwelling with plankton production.
3. Calibrate the model to the NH line time series data and examine goodness-of-fit.
4. Revise the model to improve fit to observations.
5. Apply the model to integrate seasonal zooplankton biomass and production to create a Northern California Current Biological Production Index (NCC-BPI).
6. Relate this index to early-ocean survival of juvenile salmon.
7. Compare the effectiveness of this index with other methods for forecasting salmon marine survival, with applications to forecasts needed for harvest management.

Deliverables (from proposal):

- Detailed analysis of plankton production off the Oregon Coast for 1997-2005.
- Indices of primary and secondary plankton production off the Oregon coast for earlier years (at least to 1991, possibly to 1961 depending on quality of physics data available).
- Predictive relationships between plankton production indices and Oregon coho salmon survivals (and other species as time allows).
- Presentations at scientific meetings and to harvest management agencies and committees.
- Journal article(s) describing index development and application to predicting coho salmon abundance.

Work Completed:

During the initial year of work, we consolidated Newport Hydrographic (NH) Line nutrient and plankton observations from multiple studies into a consistent database for the years 1997-2003 (later extended through 2006). This data set was used to calibrate both physics and biological components of the coupled model. Comparison of two plankton models (a simple NPZ model and the more complex PICES NEMURO model) was completed for one year of observation data (Wainwright et al. 2006a,b). This model used a simplified one-dimensional cross-shelf physics model (Newberger et al. 2003, J. Geophys. Res. 108(C3):3061, doi:10.1029/2001JC001182.) driven by the Bakun coastal upwelling index at 45° N (http://www.pfeg.noaa.gov/products/-PFEL/modeled/indices/upwelling). In addition, a preliminary calibration of the NEMURO model was completed for all years of data for three NH Line stations (NH05, NH10, NH15) under the same physics model (Wainwright et al. 2006a).

Following this preliminary work, we determined that a model of intermediate complexity would be most appropriate for our purposes, and we implemented a 6-component "NNPPZD" model, with two nutrient (nitrate and ammonium), two phytoplankton (small phytoplankton and diatoms), one zooplankton (copepods), and one detritus components (Ruzicka et al. 2006; Ruzicka et al. in prep). In addition, improvements were made to the physics model, with direct incorporation of local wind data to drive upwelling.

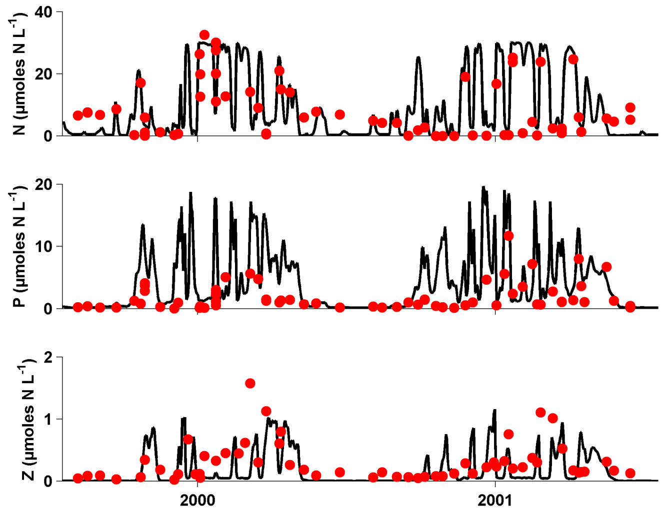

Figure 1: Comparison of the NNPPZD model (curve) and Newport Hydrographic Line observations of copepod biomass at station NH-05 (dots): top) nutrients, N, middle) total phytoplankton, P, bottom) zooplankton, Z.

In the second year of work, we (1) continued to improve the biophysical model, (2) applied the model to develop longer-term time series of biological production indices for the NCC, and (3) related the resulting indices with fish survival and production.

Changes to the model included improved calculations of wind fields driving the upwelling conveyor-belt model, improved representation of primary production, and an improved calibration technique. A rigorous calibration of this model to 2000-2001 NH line data has been completed (Ruzicka et al. in prep), resulting in good fits to nutrient, phytoplankton, and zooplankton observations (Figure 1).

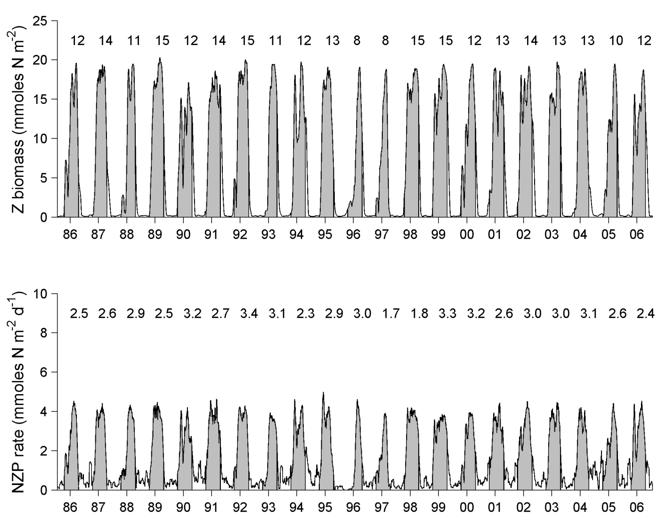

Figure 2: NNPPZD model time series from 1986 through 2006: top) zooplankton biomass summed across entire model spatial domain, bottom) net zooplankton production rate summed across entire model spatial domain. The April – September productive season for each year are highlighted in gray and the numbers above each are the seasonal means.

Once the final NNPPZD model was developed and calibrated, we used it to calculate time series of daily estimated zooplankton biomass and net production and integrated these across the upwelling season (April-September) to produce a zooplankton biomass index and a net zooplankton production ("NZP") index for each year for 1986-2006 (Figure 2).

Finally, we correlated the NZP index with the OPI index of coho salmon marine survival (Figure 3), which demonstrated a moderate positive correlation during this time period, although there is some indication that the relationship breaks down during ENSO events. The NZP index is compared with the PDO and OPI indices in Figure 4.

To compare the relative effectiveness of this biophysical modeling approach with more traditional structured time-series statistical approaches for developing fishery forecast indices, we explored the performance over time of various ocean indicators as predictors of observed salmon marine survival and/or stock abundance (Wainwright et al. 2007; Wainwright et al. in prep). Results indicate that performance of all indicators varies over time, perhaps in relation to ecosystem phase shifts or climate regime shifts (Figure 5). This makes comparison of the performance of short-term time series problematic.

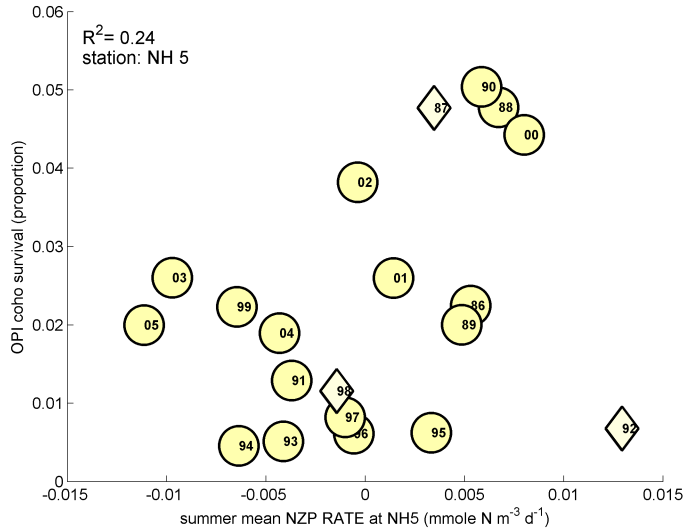

Figure 3: Relation between the Oregon Production Index, an index of juvenile coho survival over their first year at sea, and the mean summer modeled net zooplankton production rate at Newport Hydrographic Line station NH-05. (El Niño years 1987, 1992, and 1998, in diamonds, are excluded in the calculation of the correlation).

Conclusions:

Initial results from this biophysical modeling approach are not promising in terms of direct correlations with coho salmon marine survival--correlations from this approach (Figure 3) are substantially lower than recent values for some other climate indicators (Figure 5). However, while indicator correlations are often effective predictors over short time scales, they provide no mechanistic explanation, and may not reflect persistent long-term relationships (as illustrated by the large variations in performance over time in Figure 5). Our biophysical modeling approach is designed to provide a mechanistic underpinning for predictions, but this may be at the cost of reduced statistical predictive power. Future improvements in the biophysical models (for example, better representation of physical circulation and inclusion of more important salmon prey organisms in the biological model) may improve their predictive ability.

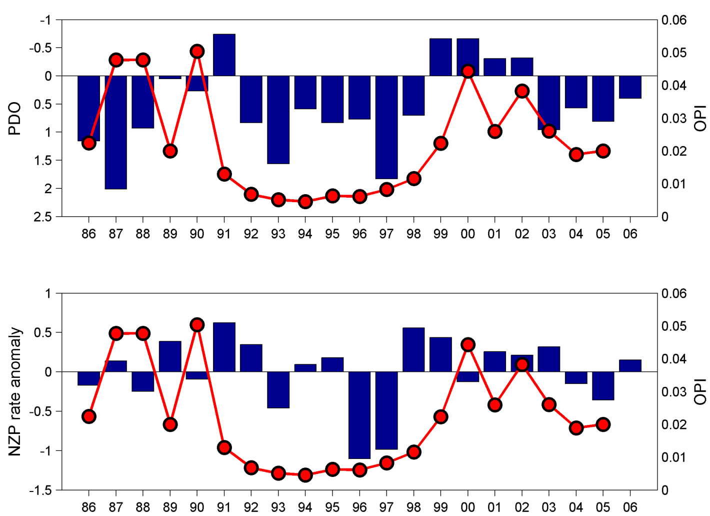

Figure 4: Time series of the Pacific Decadal Oscillation index (PDO, top), net zooplankton production rate (NZP, bottom) anomaly, and the OPI coho survival index. (PDO values are medians for each January through September. Annual NZP values are the mean seasonal values for the entire model spatial domain, and the NZP anomaly is calculated as the deviation from the mean of the annual NZP values from 1986 through 2006).

Applications:

We anticipated that the NCC-BPI would provide a measure of the

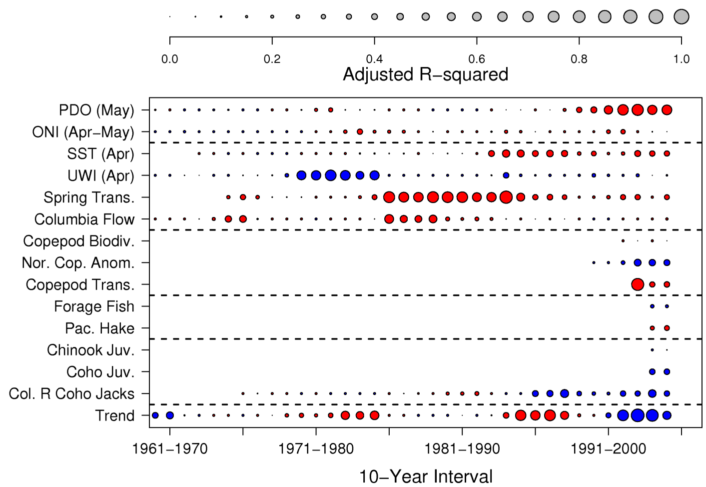

Figure 5: Variation through time in performance (adjusted R^2) of regressions of coho salmon marine survival against environmental indicators for 10-year overlapping data segments. Symbol area is proportional to R^2, red indicates negative correlation, blue indicates positive correlation. Indicators are: PDO--Pacific Decadal Oscillation, ONI--Oceanic Niño Index, SST--Sea Surface Temperature, UW--Upwelling Index, Spring Trans.--date of spring transition in sea level, Columbia Flow--discharge of the Columbia River at Bonneville, Copepod Biodiv.--copepod species richness, Nor. Cop. Anom--Northern Copepod Anomaly, Copepod Trans.--date of spring change in copepod community structure, Forage Fish.--anomalies in surveyed abundance of NCC small pelagic fishes, Pac. Hake--anomalies in survey abundance of Pacific Hake, Chinook Juv.--nomalies in survey abundance of early ocean Chinook salmon, Coho Juv.--nomalies in survey abundance of early ocean coho salmon, Col. H Coho Jacks--anomalies in jack coho salmon returning to Columbia River hatcheries; Trend--year.

effectiveness of upwelling in providing food to early-ocean salmon, thus improving predictions of salmon marine survival. To date, results show no improvement in run size forecasts from this technique compared with direct use of upwelling index (the current harvest management forecast technique).

Publications/Presentations/Webpages:

Publications:

Wainwright, T. C., L. R. Feinberg, R. C. Hooff, and W. T. Peterson. 2006a. A comparison of two lower trophic models for the California Current System. Ecol. Modelling 202(1-2):120-131.

Publications in prep:

Ruzicka, J.J., T.C. Wainwright, and W.T. Peterson. In prep. A simplified production model for the northern California Current: an evaluation of model results against time-series field data.

Wainwright, T.C., W.T. Peterson, P.W. Lawson, and E. Casillas. In prep. Environmental indicators and pacific salmon conservation. Target: *ICES Journal*.

Presentations (chronological):

Wainwright, T. C., J. J. Ruzicka, and W. T. Peterson. 2005. A biological production index for the northern California Current. PICES 14th Annual Meeting, October 2005, Vladivostok.

Ruzicka, J. J., T. C. Wainwright, and W. T. Peterson. 2006. A Simplified Production Model for the Northern California Current. AGU Ocean Sciences Meeting, February 2006, Honolulu, HI.

Wainwright, T.C. 2006b. Short-term predictability of plankton production in a coastal upwelling zone. PICES/GLOBEC Climate Change and Carrying Capacity (CCCC) Synthesis Symposium, Honolulu, April 2006.

Wainwright, T.C., R.D. Brodeur, R.L. Emmett, P.W. Lawson, W.T. Peterson, J.J. Ruzicka, L.A. Weitkamp. 2006c. Climate variation and salmon recruitment: Comparing climate indices for predicting salmon marine survival in the Northern California Current ecosystem. PICES XV Annual Meeting, Yokohama, October 2006.

Wainwright, T.C., R.L. Emmett, P.W. Lawson, W.T. Peterson. 2007. Long- and short-term performance of ecosystem indicators for coho salmon. American Institute of Fishery Biologists 50th Anniversary Symposium, Seattle, February 2007.